BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B69 10021

SUBJECT: Instrument Unit Command Communications System Anomalies During Apollo 10 and Apollo 11 Missions - Case 320

DATE: October 8, 1969

FROM: L. A. Ferrara

ABSTRACT

[redacted]

The Instrument Unit Command Communication Systems on the Apollo 10 and 11 missions each experienced similar interruptions on the down-link telemetry signal during the initial portion of the translunar coast. Investigations by MSFC personnel indicate probable causes of the failures to be improper seating of the pole pieces in the coaxial antenna switch and venting of the hermetically sealed switch housing. A new switch of improved design has been procured, tested and will be flown for the first time on Apollo 12.

The actual and calculated CCS received signal powers are compared for the Apollo 10 and 11 missions and the results of the MSFC coaxial switch investigations are summarized.

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

The Saturn V Instrument Unit Command Communications System (CCS) exhibited similar failures during the past two lunar missions (Apollo 10 and 11). In each case, the down-link S-Band telemetry signal suffered dropouts with subsequent loss of vehicle measurements data during the initial phase of the translunar coast. Satisfactory CCS performance with only some degradation in signal strength prior to the onset of the telemetry dropouts was also noted in each instance.

The Flight Evaluation Report for the Apollo 10 mission[(1)] postulated a voltage breakdown due to leakage within the hermetically sealed coaxial antenna switch which is used to route the 15 watt, S-Band signal to the High Gain, Low Gain, or Omni antennas on the IU. Post-flight vacuum chamber testing of a similar coaxial switch which had a small hole drilled through the case exhibited sudden signal attenuation when a critical pressure was reached and a near normal restoration of signal when the pressure decreased beyond the critical pressure region.

A coaxial switch of a new design has been procured and vacuum chamber tested by MSFC with satisfactory results. The new switch will not be flown until AS-507 (Apollo 12). Because of time limitations, the Apollo 11 mission was flown with the original type switch; similar CCS failure was anticipated and experienced. Subsequent vacuum chamber tests on the Apollo 11 type switch showed the failure mode to be associated with arcing between the switch terminals. The failure analyses reported in Reference 2 attributes the cause of arcing to improper seating of the switch contacts when a change in IU Antenna routing was commanded.

This memorandum summarizes the failure reports made in References 1 and 2. It further shows the time history of the received signal strengths during the period of dropouts and compares them with the calculated received signal power.

2.0 ANALYSIS

The time histories of the IU CCS signal as received by the 30 foot diameter antennas at MSFN sites of Guaymas (for Apollo 10) and Hawaii (for Apollo 11) are shown in Figures 1 and 2, respectively. Also shown on these figures is the calculated received signal power for the nominal case as computed by the program listed in Reference 5.

Comparison of the calculated and actual received signal power curves during the periods of relatively steady signal for the Apollo 10 case (Figure 1) shows the actual signal to be 4 dB less than calculated before the first major power dip ($6^h:34^m$ GET). This could be explained by a less favorable antenna look angle than was used in the calculations, which are based on parameters given in Reference 4. This difference in signal power could also indicate that some gradual attenuation was already effecting the CCS RF system. It is clear, however, that when the CCS signal recovered at $6^h:58^m$ (GET) after switching to the omni antenna mode, an additional 5 dB attenuation was present in the system. The S-IVB was not maneuvering during this period, and the MSFC report[(1)] indicates that constant helix coil current was maintained in the power amplifier throughout the period of the dropouts.

The Apollo 11 mission (Figure 2) shows the CCS actual received signal power to be 13 dB less than calculated after the first major dropout at $7^h:32^m$ (GET) and this differential was maintained when the final switch to the omni antenna feed was made just prior to the loss of signal at $9^h:45^m$ (GET).

A mathematical solution could not be found in the references to specifically substantiate the breakdown phenomenons at a pressure of 18 mm of Hg. (equivalent to the pressure chamber altitude of 80,000 ft. as tested by MSFC). Reference literature does, however, support the MSFC contention that the Apollo 10 and 11 CCS problem could have been caused by the slowly venting coaxial switch. Venting of the sealed cavity over a period of hours in outer space probably caused RF leakage to gradually develop and subsequently arc over at a pressure around 18 mm Hg. The arc could have been maintained until the coaxial switch case was almost completely evacuated, at which time the ionized air which sustained the arc would have been depleted.

The maximum electron field in coaxial cables is at the surface of the inner conductor (this is assumed to be equivalent to the feed-through or input pole of the coaxial switch). At higher pressures such as 1 atmosphere (the pressure at which the switch was sealed), the breakdown tends to form at the surface of the inner conductor. The breakdown point moves outward radially as the pressure decreases, because the electrons have a larger mean-free path before colliding with a gas molecule and causing the ionization. This ionization creates the arc (which in turn causes the RF short) as well as leaving, in most cases, a high resistance burn in the insulating material such that, even when the arc is extinguished, a leakage path will remain which can shunt a significant portion of the RF energy, thereby reducing the radiated power.

Of the many configurations analyzed in Reference 3, the most nearly analogous situation to the CCS coaxial switch with an unseated contact is the short monopole antenna (less than $\frac{\lambda}{4}$), where the input feed to the switch would be considered the monopole. The minimum RF power which can initiate and sustain RF breakdown in a monopole antenna varies somewhat with frequency, monopole size and tip shape. RF powers between 10 and 20 watts, however, have been proven to initiate and maintain breakdown of a short monopole antenna in a pressure regime between 8 to 20 mm Hg. These results are apparently in good agreement with the findings of the MSFC vacuum chamber tests of the coaxial switch in which breakdown first occurred when a pressure of 18 mm of Hg. was reached while applying the nominal 15 watts of power to the vented switch.

3.0 SUMMARY

The MSFC analyses of the CCS failures on the Apollo 10 and 11 missions appear to be verified by the results reported in Reference 3. A new switch of improved design will be flown for the first time on Apollo 12. This new switch incorporates the following improved design features:[6]

1. The contacts are more substantial and are seated with greater contact pressure.

2. The contacts are make-before-break instead of the break-then-make design of the older version.

3. The switch case is sealed by an "O" ring and flange screws instead of the solder seal used in the earlier

units, some of which experienced seal rupture (and subsequent venting) during vibration testing.

4. The layout of the internal elements of the new switch eliminates RF leakage even when the vented test article was cycled through the critical pressure region.

These improvements should be adequate to correct the CCS RF problems which occurred during Apollo 10 and 11, thereby permitting continuous down-link telemetry from the Instrument Unit until the threshold limits of the MSFN ground stations are reached.

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L. A. Ferrara

Attachment
Figures 1 and 2

REFERENCES

1. "Saturn V Launch Vehicle Flight Evaluation Report - AS-505 Apollo 10 Mission," MSFC, July 15, 1969.

2. Minutes of the AS-506 Flight Evaluation Working Group, MSFC, August 5, 1969.

3. Morita, T. and Scharfman, W. E., "Voltage Breakdown of Antennas at High Altitudes," Stanford Research Institute Technical Report 69, April, 1960.

4. "Saturn V Launch Vehicle Instrumentation/MSFN," Performance and Instrumentation Specification 50M13106, June, 1967.

5. Schroeder, N. W., "Communications Margins for Apollo Unified S-Band Links with Phase Modulation," TM 68-2034-17, December 31, 1968.

6. Private communication with Mr. N. Poarch/I-V-IU/Marshall Space Flight Center.

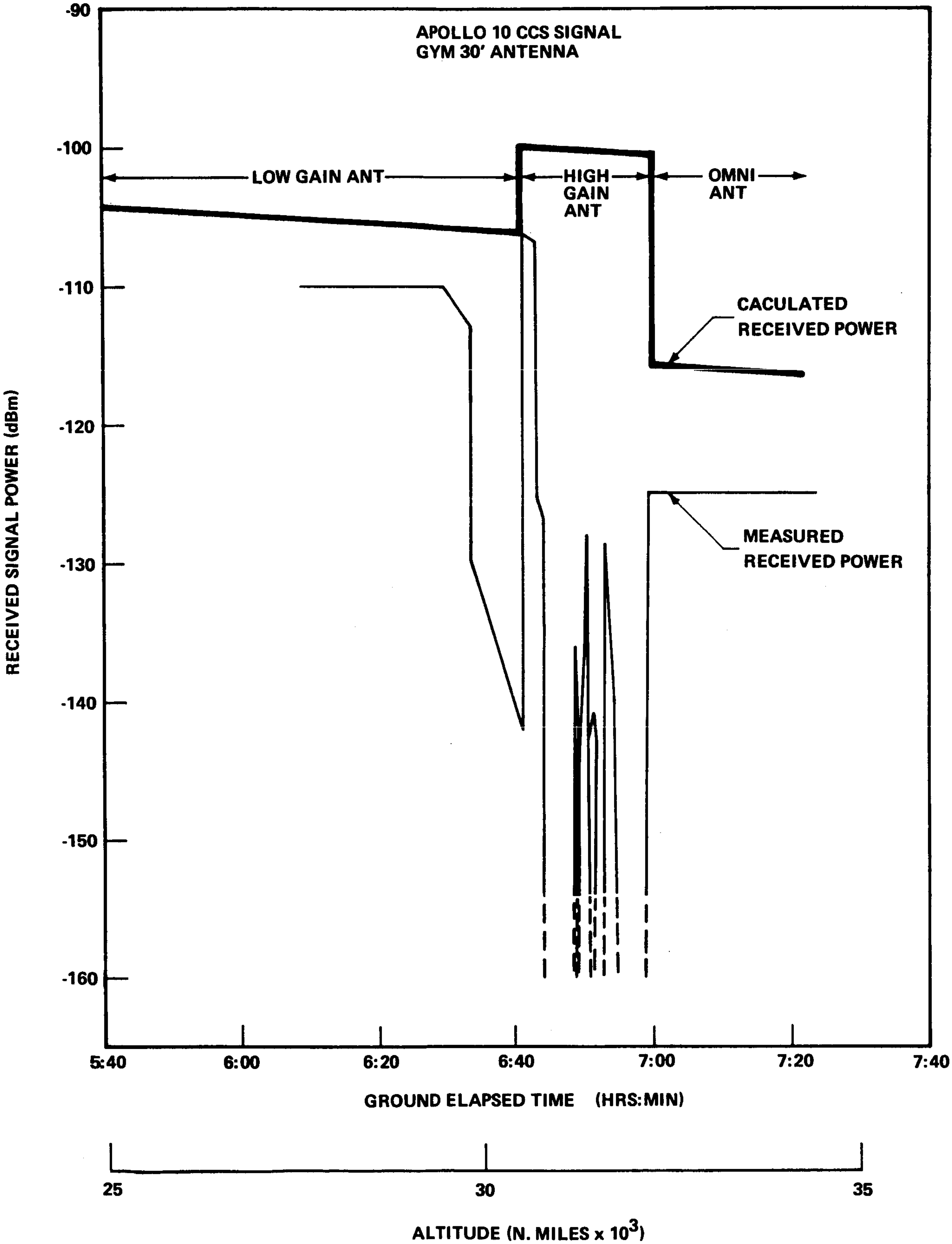

FIGURE 1 - IU COMMAND COMMUNICATIONS SYSTEM RECEIVED SIGNAL COMPARISON

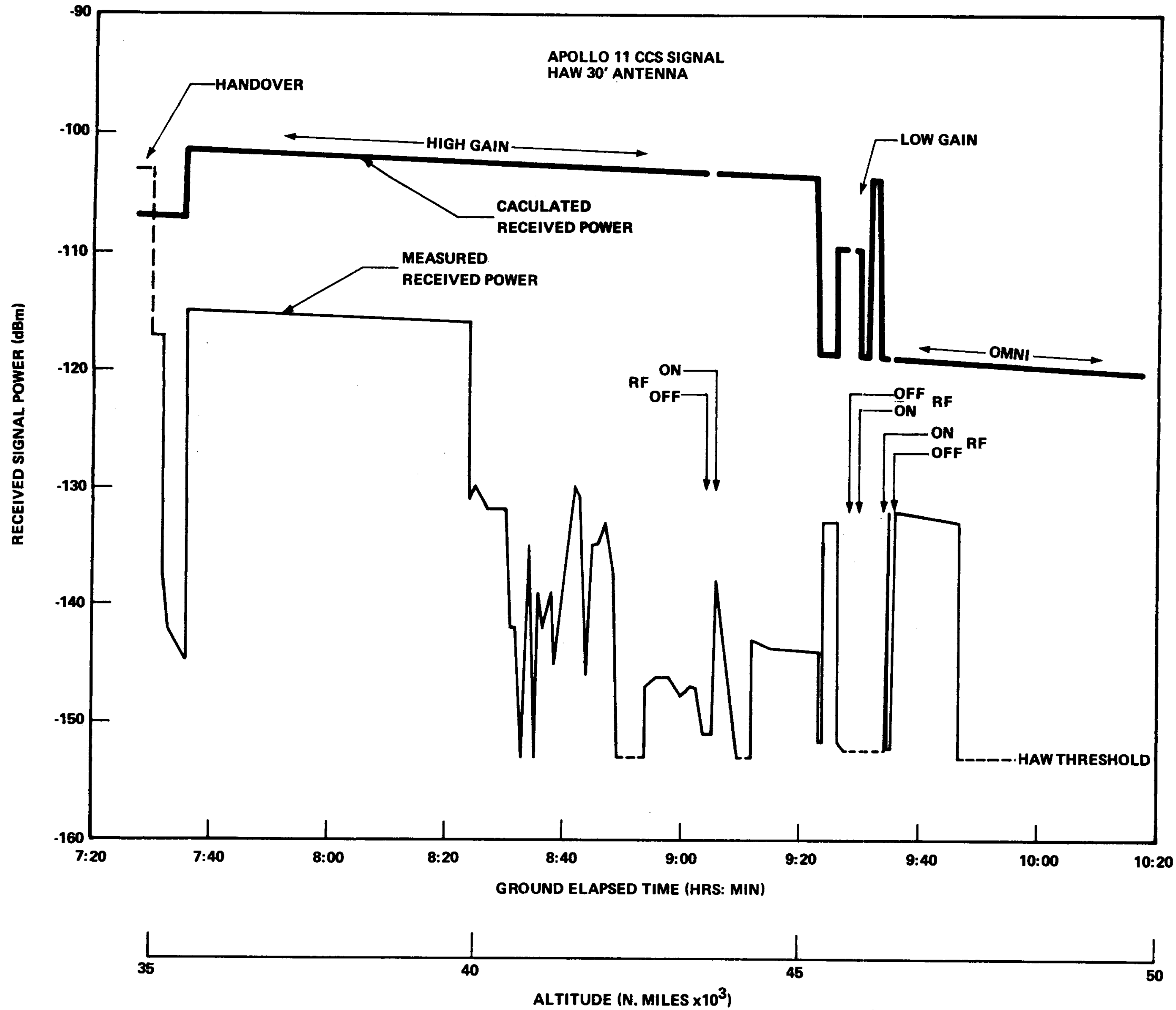

FIGURE 2 - IU COMMAND COMMUNICATIONS SYSTEM RECEIVED SIGNAL COMPARISON

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